CHAPTER 9

ELECTRICAL SYSTEMS AND PLAN

It is important for an EA working on a set of drawings or plans to convey his ideas (or instructions) effectively to a skilled craftsman (CE) who is to install the electrical system. It is also equally important for you, as an EA, to understand and be thoroughly familiar with the methods and basic functions associated with the different materials and fixtures used in the installation of an electrical system.

This chapter, when used in conjunction with the previous chapters on wood, concrete and masonry, and mechanical systems and plan, will enable you to prepare construction drawings (discussed in the next chapter), revise as-built drawings in the field, and incorporate minor design changes with ease.

ELECTRICAL SYSTEM

Each building requires an electrical system to provide power for the lights and to run various appliances and equipment. At Navy bases, the electrical (or power) system consists of three main parts: the power plant that supplies the electrical power, the electrical distribution system (external) that carries the electrical current from the generating station to the various buildings, and the interior electrical wiring system that illuminates the building and feeds the interior electrical power to the appliances and equipment within the building.

In this section, we will discuss only the external power distribution and the various materials and fittings used in the installation of an electrical system. For more information, refer to the latest edition of *Construction Electrician 3 & 2*, NAVEDTRA 10636, *National Electrical Code*®(NEC®), and Army Technical Manuals (TMs).

ELECTRICAL (POWER) DISTRIBUTION SYSTEM

Electrical distribution is defined as the delivery of power to building premises, on poles or placed underground, from the power plant or substation through feeders and mains.

The power system is generally considered to be a combination of two sections: the transmission and the distribution. The difference between the two sections depends on the function of each at that particular time.

At times, in a small power system, the difference tends to disappear, and the transmission section merges with the distribution section. The delivery network, as a whole, is referred to as the distribution section and is normally used to designate the outside lines and frequently continues inside the building to include power outlets.

Most land-based power systems use alternating current (ac) rather than direct current (dc), principally because transformers can be used only with ac. An ac distribution system usually contains one or more generators (technically known as ALTERNATORS in an ac system); a wiring system of FEEDERS, which carry the generated power to a distribution center; and the DISTRIBUTION CENTER, which distributes the power to wiring systems called PRIMARY MAINS and SECONDARY MAINS. A representative transmission and distribution system is shown in figure 9-1.

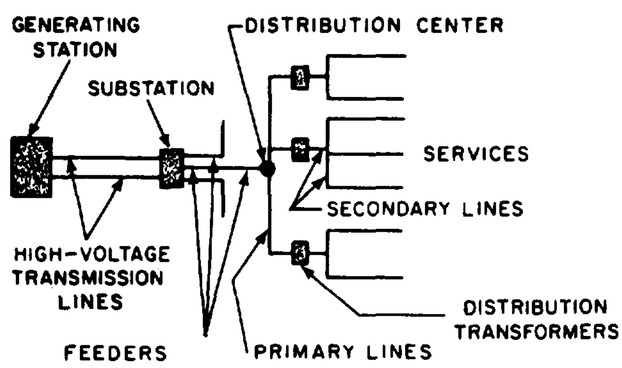


Figure 9-1.-Electrical transmission and distribution system.

Power from the generating station may be carried to the various points of consumption by overhead transmission and distribution lines, by underground cable, or by a combination of both. At most advanced bases, OVERHEAD feeder lines are commonly used because such lines are cheaper to build, simpler to inspect, and easier to maintain than UNDERGROUND cables. Obviously, the use of underground cables is preferred at airports and runways to prevent hazardous flight conditions.

Overhead Power Distribution

Figure 9-2 shows a three-phase, three-wire OVERHEAD power distribution system. Assume that the system has an alternator generating 220 V (fig. 9-3). From the generating station, three-phase, three-wire feeders carry the power overhead to the distribution points (or centers), from which two primary mains branch off. One of these mains carries power to a lighting system and a single-phase motor in a motor pool, each of which is designed to operate on 110 V, and to a three-phase motor designed to operate on 220 V. The 220-V, three-phase motor is connected directly to the 220-V, three-phase primary main. However, for the lighting system and 110-V motor, two wires in the primary main are tapped off to a transformer, which reduces the 220-V primary main voltage to 110 V. The use of two wires creates a single-phase voltage in the secondary main to the motor pool. Similarly, power to secondary mains running to the operational headquarters, living quarters, and the mess hall is reduced to 110 V and converted to single phase.

A system may be a THREE-WIRE or a FOUR-WIRE system, depending upon whether the alternators are connected DELTA (A) or WYE (Y). Figure 9-4 is a schematic diagram showing a delta connection. The coil marked

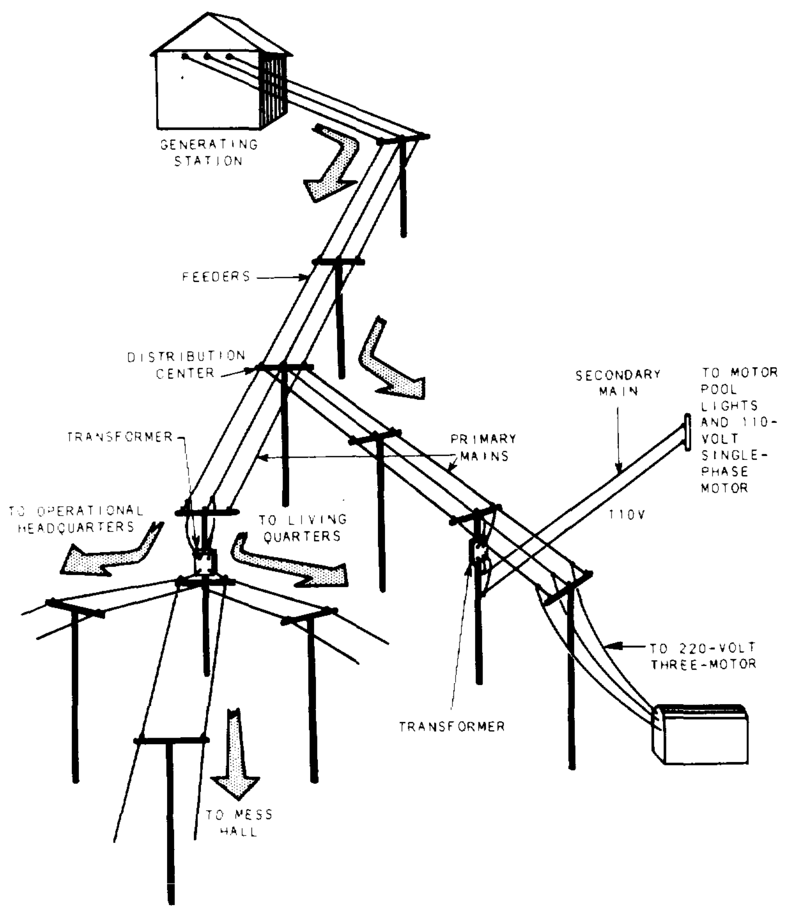


Figure 9-2.-A typical overhead power distribution system.

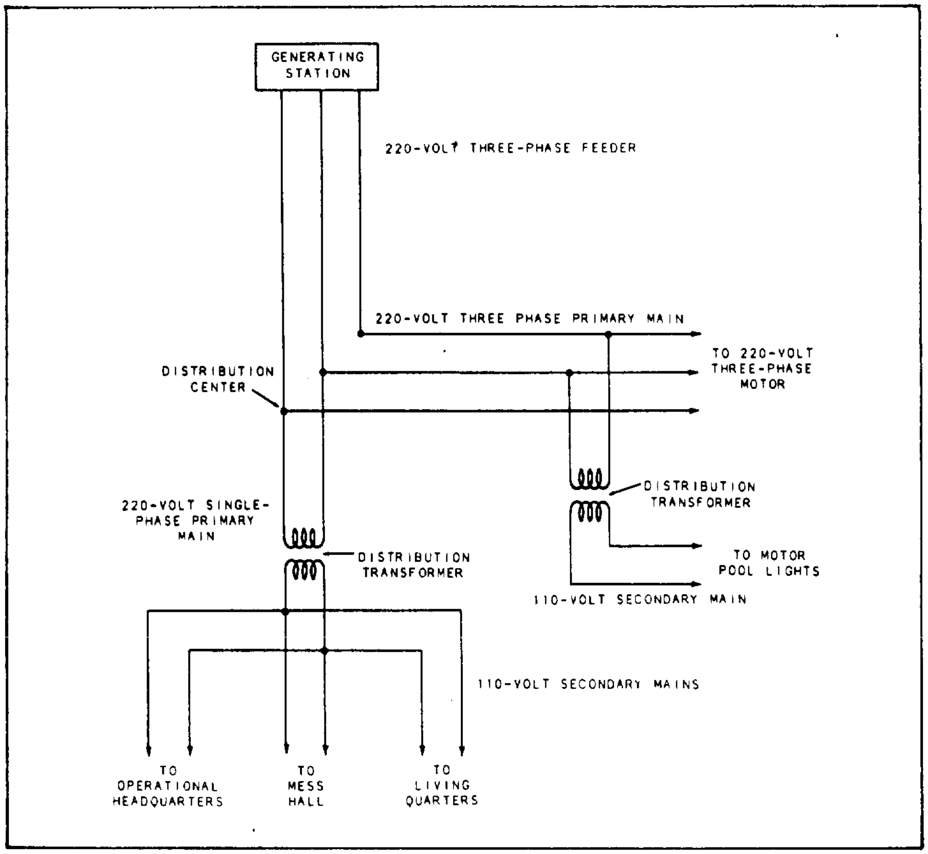


Figure 9-3.-Wiring diagram of the three-phase, three-wire distribution system in figure 9-2.

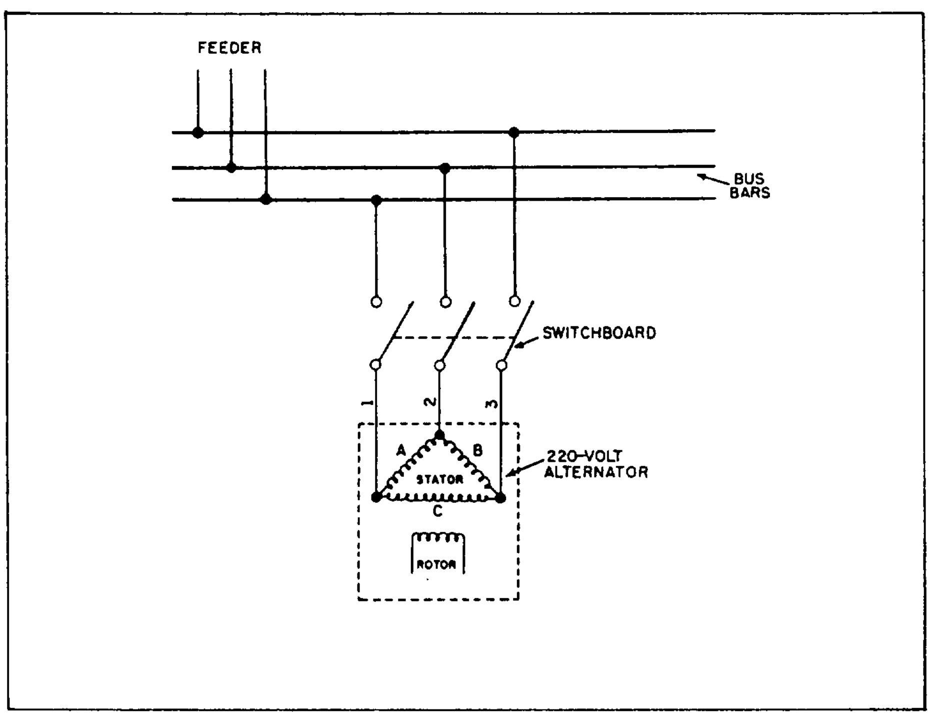


Figure 9-4.-Schematic diagram of a delta-connected alternator.

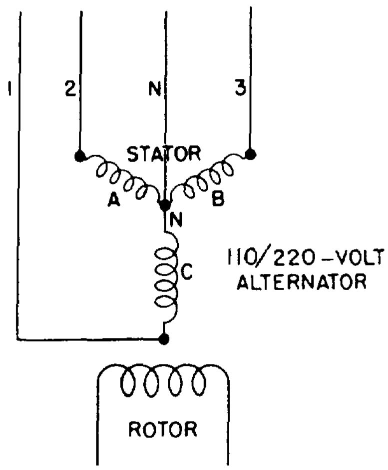


Figure 9-5.-Y-connected alternator (three-phase, four-wire).

STATOR represents the stationary coils of wire in the alternator; the one marked ROTOR represents the coils, which rotate on the armature. You can see that the power is taken off the stator from three connections, which in the drawing form a triangle or delta. All three wires are live (called HOT) wires.

Figure 9-5 shows a Y-connected alternator (three-phase, four-wire). N represents a common or NEUTRAL point to which the stator coils are all connected. The current is taken off the stator by the three lines (wires), 1, 2, and 3, connected to the stator coil ends; and also by a fourth line, N, connected to the neutral point. Lines 1, 2, and 3 are hot wires; line N is NEUTRAL.

The voltage developed in any pair of wires, or in all three wires, in a delta-connected alternator is always the same; therefore, a

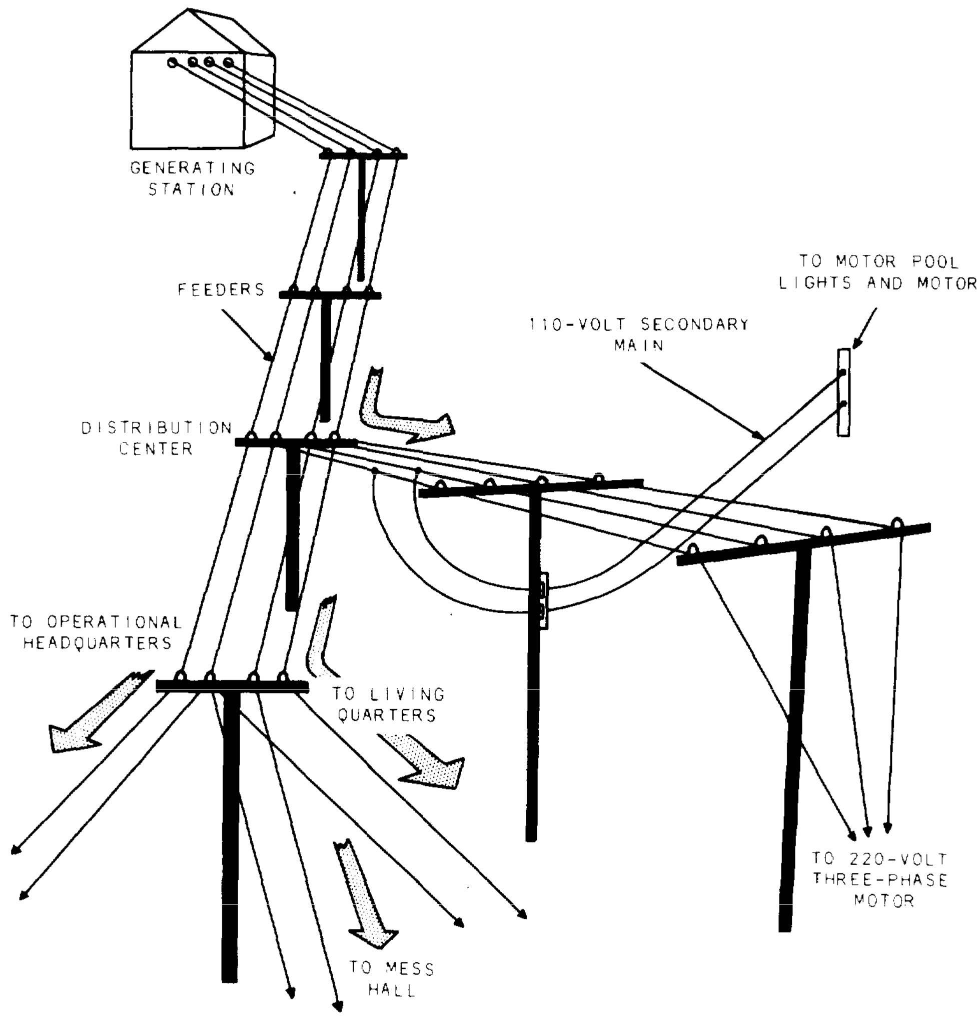


Figure 9-6.-A pictorial view of a four-wire overhead distribution system.

delta-connected system has only a single voltage rating (220 V in fig. 9-4). However, in a Y-connected system, the voltage developed in different combinations of wires is different. In figure 9-5, you can see that lines 1 and 2 take power from two stator coils (A and C). The same applies to lines 1 and 3 (power from coils C and B) and lines 2 and 3 (power from coils A and B). However, the neutral (N) and line 2 take power from coil A only; neutral (N) and line 1, from coil C only; and neutral (N) and line 3, from coil B only.

It follows from this that a Y-connected alternator can produce two different voltages: a higher voltage in any pair of hot wires, or in all three hot wires, and a lower voltage in any hot wire paired with the neutral wire.

Output taken from a pair of wires is SINGLE-PHASE voltage; output from three wires is THREE-PHASE voltage. The practical significance of this lies in the fact that some electrical equipment is designed to operate only on single-phase voltage, while other equipment is designed to operate only on three-phase voltage. This equipment includes the alternators themselves, and a system with a three-phase alternator is called a three-phase system. However, even in such a system, single-phase voltage can be obtained by tapping only two of the wires.

Figure 9-6 shows a four-wire system serving the same facilities. Here there is a Y-connected alternator rated at 110/220 V. You can see that to get 110 V single phase for the secondary mains, no transformers are necessary. These mains are simply tapped into pairs of wires, one of each pair being a hot wire and the other, the neutral wire. The 220-V, three phase motor is tapped into the three hot wires that develop 220 V, three-phase. You can see that the neutral wire in a four-wire system exists to make it possible for a lower voltage to be used in the system.

Figure 9-7 shows a wiring diagram for the system shown in figure 9-6.

Now, let's discuss the device called a DISTRIBUTION TRANSFORMER. A transformer is simply a device for increasing or reducing the voltage in an electrical circuit. It ranges in size from one that is portable (those used for appliances inside the building) to heavy ones that are mounted permanently on platforms or

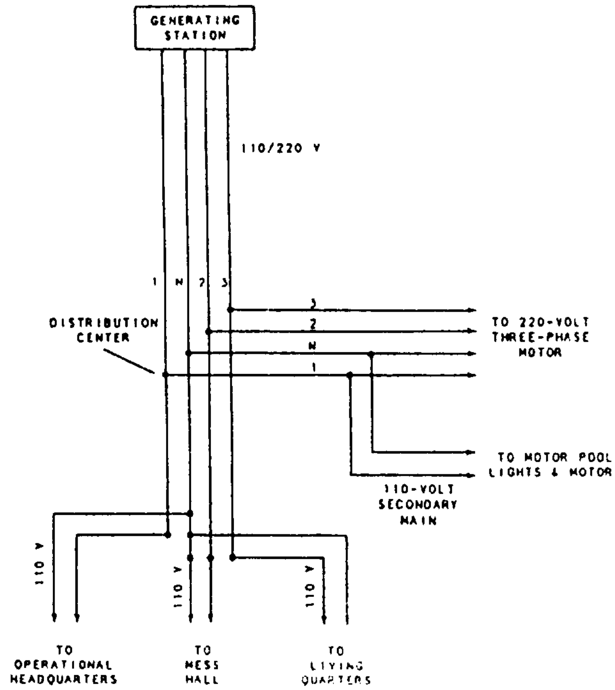


Figure 9-7.-Wiring diagram of the four-wire system in figure 9-6.

hung with crossarm brackets attached to an electric pole. Ask one of the CES to show you a transformer. It is very probable that one is nearby.

Now, for long-distance power transmission, a voltage higher than that normally generated is required. A transformer is used to step the voltage up to that required for transmission. Then at the service distribution end, the voltage must be reduced to that required for lights and equipment. Again a transformer is used; but this time it is to step down the voltage.

The reason for stepping up the voltage in a line lies in the fact that the greater the distance, the more resistance there will be to the current flow; and a much greater force will be required to push the current through the conductor. Perhaps you can best understand this reasoning if you examine Ohm's Law.

$$I = \frac{E}{R}.$$

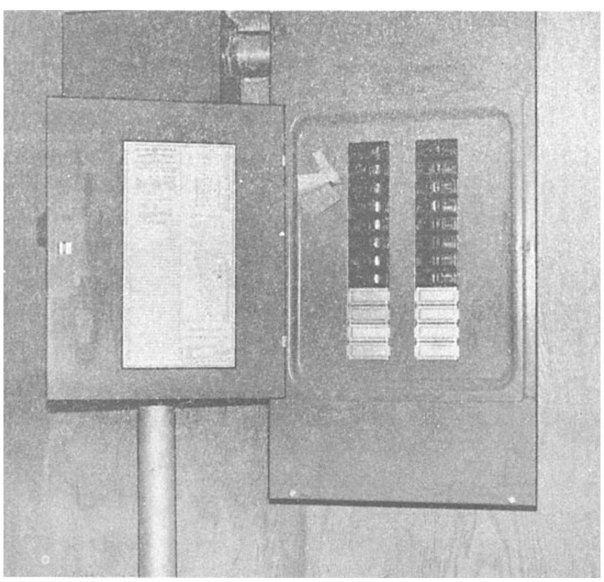
(Refer to chapter 1 of this book.)

You can see from the formula above that the CURRENT (I) varies inversely to the RESISTANCE (R). To maintain the required current flow disconnecting the service conductors from the supply source. It may consist of a single manually operated switch or a circuit breaker. The NEC® sets a minimum size for entrance switches at 60 A for the fuse type and 50A for the circuit breaker type. A CIRCUIT BREAKER is a protective device that automatically opens the circuit, rather than burning out like a fuse, when the amperage exceeds that rated for the circuit breaker. The NEC® recommends a minimum size of 100-A service for individual residences. However, when not more than two two-wire branch circuits are installed, a 30-A entrance switch may be used.

Panelboard

A PANELBOARD (fig. 9-10) is defined by the NEC® as a single panel, or a group of panel units designated for assembly in the form of a single panel, including buses. It comes with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity; it is designed to be placed in a cabinet or a cutout box and placed in or against a wall or partition and is only accessible from the front.

A BREAKER PANEL uses a thermal unit built into the switch with the breaker being preset at the factory to open automatically at a predetermined



73.11

Figure 9-11.-Lighting panel.

ampere setting. It maybe reset to the ON position after a short cooling-off period.
LIGHTING PANELS (fig. 9-11) are normally equipped with 15-A single-pole automatic circuit breakers, while the power panels may have one-, two-, or three-pole automatic circuit breakers with a capacity to handle the designated load. In most buildings, the entrance switch and panelboards can be mounted close to each other; however, they must be placed where service and maintenance can be easily performed. They should not block any passage that is supposed to be open, and they should not be in a place where exposure to corrosive fumes and dampness is imminent. Panelboards should be located as near as possible to the center of the electrical load.

Conductors

ELECTRICAL CONDUCTORS generally consist of drawn copper or aluminum formed into wire. They provide paths for the flow of electrical current. Conductors are usually covered with insulating materials (fig. 9-12) to minimize the

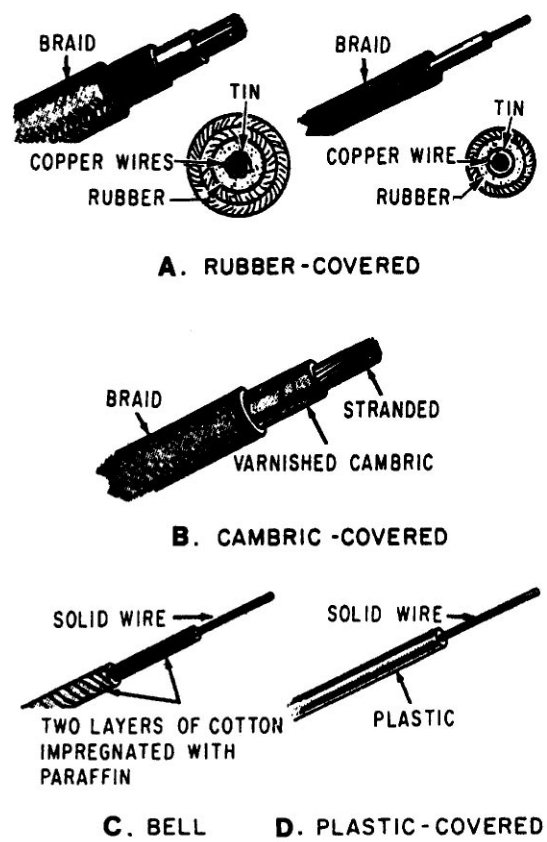


Figure 9-12.-Types of single insulated conductors.

chances for short circuits and to protect personnel. Atmospheric conditions, voltage requirements, and environmental and operating temperatures are factors to consider in selecting the type of insulating material for a particular job.

SINGLE CONDUCTORS.— A single conductor may consist of one solid wire or a number of stranded, uncovered, solid wires that share in carrying the total current. A stranded conductor has the advantage of being more flexible than a solid conductor, making it more adaptable for pulling through any bends in a conduit. Common types of single conductors are shown in figure 9-12.

Conductors vary in diameter. Wire manufacturers have established a numerical system, called the American Wire Gage (AWG) Standard, to eliminate the necessity for cumbersome circular mil or fractional-inch diameters in describing wire sizes. Figure 9-13 shows a comparison of one-half actual wire diameters to their AWG numerical designations. Notice that the wire gauge number increases as the diameter of the wire decreases.

The wire size most frequently used for interior wiring is No. 12 AWG and is a solid conductor. No. 8 and larger wires are normally used for heavy power circuits or as service entrance leads to buildings.

The type of wire used to conduct current from outlet boxes to sockets in the lighting fixtures is called "fixture wire." It is stranded for flexibility and is usually size 16 or 18 AWG.

AWG NUMBER	½ ACTUAL SIZE	DIAMETER (INCHES)
18	•	.0403
16	•	.0508
14	•	.0640
12	•	.0808
10	•	.1018
8	•	.1284
6	•	.184
4	•	.232
2	•	.292
1	•	.332
1/0	•	.373
2/0	•	.419
3/0	•	.470
4/0	•	.528

Figure 9-13.—Comparison of standard wire gauge number to wire diameters.

MULTIWIRE (CABLE) CONDUCTORS.— A multiwire conductor, called a CABLE, is an assembly of two or more conductors insulated from each other with additional insulation or a protective shield formed or wound around the group of conductors. The covering or insulation for individual wires is color coded for proper identification. Figure 9-14 shows common types of multiwire conductors.

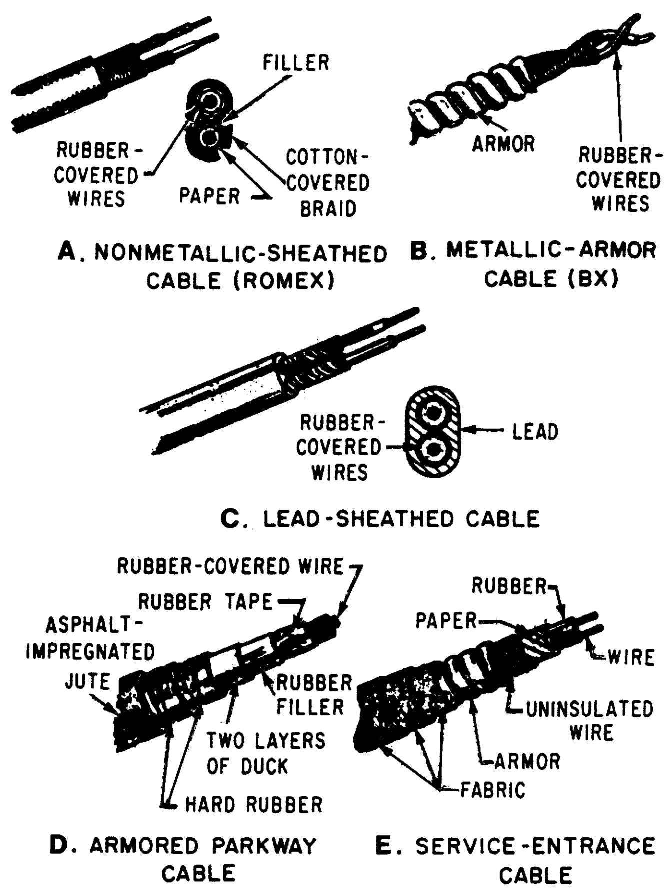


Figure 9-14.—Types of multiwire insulated conductors (cables).

Nonmetallic-sheathed cable (NMC) (fig. 9-14, view A) is more commonly called by the trade name "ROMEX," ROMEX (NMC) comes in sizes No. 14 through 2 for copper conductors and No. 12 through 2 for aluminum or copper-clad aluminum conductors. This type of cable comes with a bare (uninsulated) ground wire. The ground wire is laid in the interstices (intervals) between the circuit conductors and under the outside braid. The ground wire is used to ensure the grounding of all metal boxes in the circuit, and also to furnish the ground for the grounded type of convenience outlets that are required in Navy installations. Nonmetallic-sheathed cable is used for temporary wiring in locations where the use of conduit would be unfeasible. The use of Romex as service entrance cable, in garages, in storage battery rooms, imbedded in poured concrete, or in any hazardous area is NOT authorized.

Metallic-armored cable (fig. 9-14, view B), also called BX cable, is used in naval installations for temporary wiring, but unlike Romex, its use in commercial installation is restricted. Most city building codes restrict the use of BX cables to oil burner control circuits and the like. A difficulty with BX is the fact that it tends to ground after installation. Small metal burrs on, the armor can, because of vibration, penetrate the insulation and cause a ground.

BX cables come in sizes from No. 14 to 2 AWG, and each cable may contain one, two, three, or four conductors. The armor on the cable furnishes a continuous ground between boxes.

Insulation

As mentioned earlier, electrical conductors are available with various kinds of insulating materials. Some of these are rubber, thermoplastic, and varnished cambric. Special types of paper, glass, silk, and enamel are also used to insulate conductors, but with less frequency than those previously mentioned. The NEC® recommends insulation of certain kinds for use in dry, damp, and wet locations. Underground installations, those in concrete slabs and masonry, those in direct contact with the earth, and those subject to saturation with water or other liquids are considered wet-location installations.

Another factor to consider in the choice of insulation is temperature. Different insulations have different maximum temperature ratings. Check the NEC® and applicable LOCAL CODES to be sure you are using the appropriate insulation for the location and temperature considered in the plans. Some examples of the composition of insulation, the location that applies, and their maximum temperature rating follow:

Type RH is a heat-resistant compound, that will stand higher temperature than Type R. This type is commonly used in dry locations. The maximum temperature rating is 167°F.

Type RHW is a moisture-resistant rubber compound for use where the wire may be subject to wet conditions. This type is used in both wet and dry locations. The maximum temperature rating is 167°F.

Type RUH is a high grade rubber compound, consisting of 90-percent latex. This type is often used for direct burial in dry locations. The maximum temperature rating is 140°F.

Thermoplastic insulation has the advantage of long life, toughness, and a dielectric strength (that is, a capacity for insulating) equal to that of rubber. It requires no protective covering over the insulation. Common types of thermoplastic insulation are Types T, TW, and TA. Type T is suitable only for dry locations with a maximum temperature rating of 140°F. Type TW is moisture-resistant, and again, with a temperature rating of 140°F. Type TA is a thermoplastic-asbestos compound that combines the characteristics of Types T and TW. This type has a maximum temperature rating of 194°F. Its use is restricted to switchboard wiring.

Varnished cambric insulation has an insulating quality midway between that of rubber and paper. It is more flexible than paper; its dielectric strength is greater than that of rubber. This type is not adversely affected by ordinary oil and grease. It is manufactured in either standard type (black finish), or in the heat-resistant type with a yellow finish. Varnished insulation is restricted to dry locations in areas such as motor leads, transformer leads, and high-voltage cables.

Conduits and Fittings

An electrical conduit is a pipe, tube, or other means in which electrical wires are installed for protection from accidental damage or from the elements. If pipes or tubing is used, the fittings depend upon the pipe or tubing material. The conduit used in Navy construction is generally classified as RIGID, THIN-WALL, or FLEXIBLE conduit. The three types of conduit and their associated fittings are shown in figure 9-15.

RIGID CONDUIT.— Rigid galvanized steel or aluminum conduit is made in 10-ft lengths. It is threaded on both ends and comes with a coupling on one end. It comes in sizes from 1/2 in. to 6 in. in diameter. Various fittings used

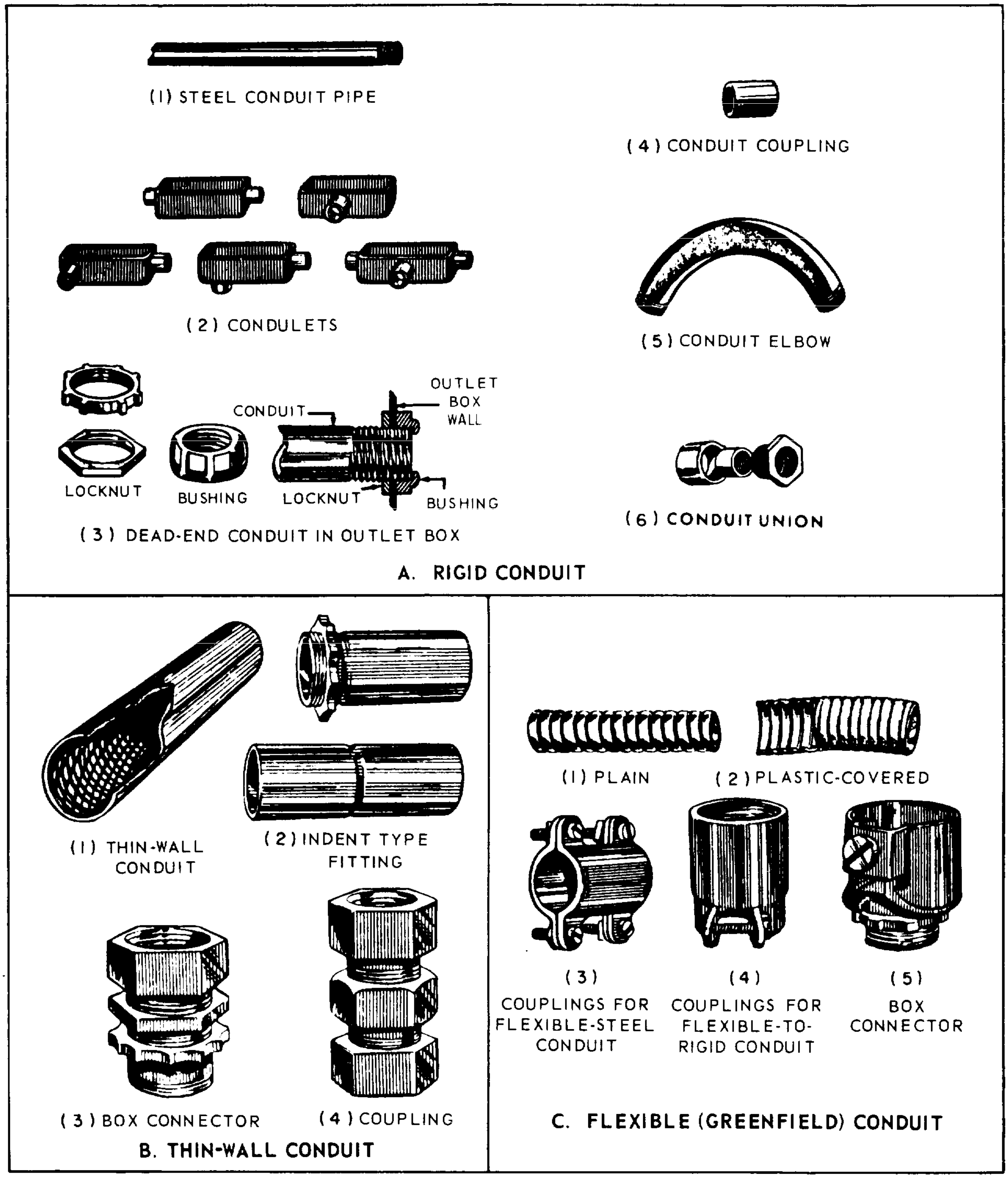


Figure 9-15.-Types of conduit and their associated fittings.

for connecting rigid metal conduit are shown in figure 9-15, view A. The use of rigid conduit involves a good deal of cutting, bending, and threading of lengths. An ordinary hacksaw or special wheel pipe cutter is used for cutting, while a ratchet type of mechanical die is used for thread-cutting conduit pipes. Bending of pipes can be undertaken both manually, using a bending tool commonly called a hickey, and hydraulically. A hydraulic bender is recommended for making smooth and accurate bends.

CONDULETS (fig. 9-15, view A (2)) are a convenient way of making bends, especially in conduit that will be exposed to the elements. They are heavily used on sharp corners and also to reduce the number of bends made in a run of conduit.

Another type of rigid conduit approved for use by NAVFAC is the polyvinyl chloride (PVC) pipe. This now popular plastic conduit is specially suitable for use in areas where corrosion of metal conduits has been a problem. Some of the advantages of PVC conduit are as follows: light handling weight, ease of installation, and leakproof joints. This conduit is primarily intended for underground wire and cable raceway use and is made in two forms. Type I is designed for concrete encasement, and Type II is designed for direct earth burial. Rigid plastic conduit and fittings are joined together by a solvent-type adhesive welding process. It also comes in sizes of 1/2 to 6 in. in diameter. PVC fittings are also available from the manufacturer. (For more information on PVC fittings, refer to Article 370 of the NEC®.)

THIN-WALL CONDUIT.— Electric metallic tubing (EMT) or thin-wall conduit, as it is better known, is a type of conduit with a wall thickness quite a bit less than the rigid conduit. It is made in sizes from 1/2 to 2 in. in diameter. Thin-wall conduit cannot be threaded; therefore, special types of fittings (fig. 9-15, view B) must be used for connecting pipe to pipe to boxes.

FLEXIBLE CONDUIT.— Flexible conduit (fig. 9-15, view C), also called Greenfield, is a spirally wrapped metal band wound upon itself and interlocking in such a manner as to provide a round cross section of high mechanical strength and flexibility. It is used where rigid conduit would not be feasible to install and requires no elbow fittings. It is made in sizes from 1/2 to 3 in. in diameter. Greenfield is available in two types: the plain or standard unfinished-metal type and a moisture-resistant type called sealtite, which has a plastic or latex jacket. The moisture-resistant type is not intended for general use but only for connecting motors or portable equipment in damp or wet locations and where flexibility of connections is desired.

Wire Connectors

Figure 9-16 shows various types of connectors that are used to join or splice conductors. The type used will depend on the type of installation and the wire size. Most connectors operate on the same principle, that of gripping or pressing the conductors together. WIRE NUTS are used extensively for connecting insulated single conductors installed inside of buildings.

Outlet Boxes

OUTLET BOXES bind together the elements of a conduit or cable system in a continuous

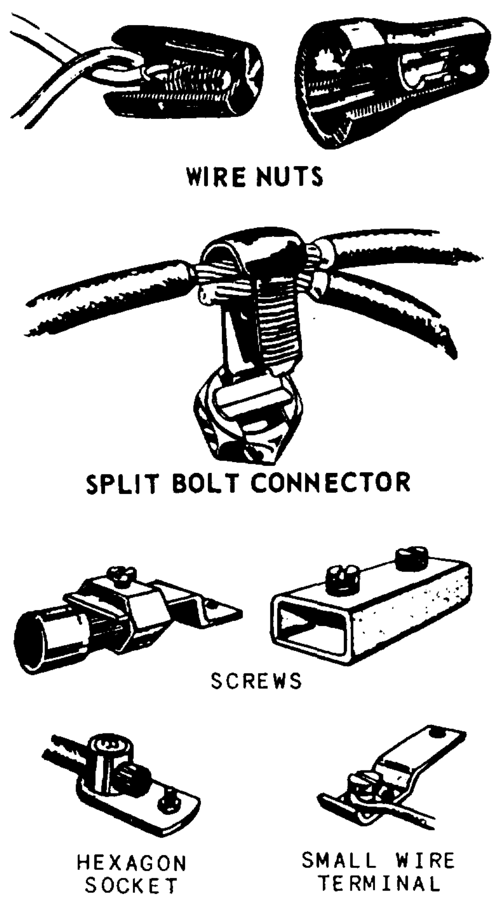


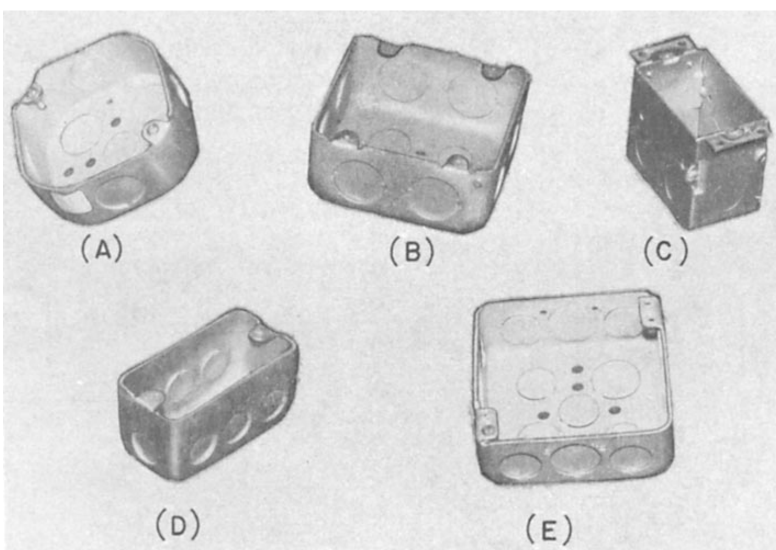
Figure 9-16.-Types of cable and wire connectors.

grounded system. They provide a means of holding the conduit in position, space for mounting such devices as switches and receptacles, protection for these devices, and space for making splices and connections. Outlet boxes used in Navy construction are usually made of galvanized steel; however, nonmetallic boxes, such as rigid plastic compounds, are being used for approved installation. Boxes are either round, octagonal, square, or rectangular in shape. Commonly used outlet boxes are shown in figure 9-17.

An outlet box is simply a metal container, set flush or nearly flush with the wall, floor, or ceiling, into which the outlet receptacle or switch will be inserted and fastened. Figure 9-17, view A, is a 4-in. octagon box used for ceiling outlets. This box is made with 1/2- or 3/4-in. KNOCKOUTS—indentations that can be knocked out to make holes for the admission of conductors and connectors. Figure 9-17, view B, shows a 4 11/16-in. square box used for heavy duty, such as for a range or dryer receptacle. It is made with knockouts up to 1 in. in diameter. Figure 9-17, view C, is a sectional or GEM BOX used for switches or receptacles. By loosening a screw, you can remove the side panel on the gem box so that two or more boxes can be GANGED (combined) to install more than one switch or receptacle at a location. Figure 9-17, view D, is a UTILITY BOX, called a handy box, made with 1/2- or 3/4-in. knockouts and used principally for open-type work. Figure 9-17, view E, is a 4-in. square box with 1/2- or 3/4-in. knockouts, used quite often for switch or receptacle installation. It is equipped with plastic rings having flanges of various depths so that the box may be set in plaster walls of various thicknesses.

Besides the boxes shown, there are special boxes for switches when more than two switches at one location are required. These are called CONDUIT GANG BOXES, and they are made to accommodate three, four, five, or six switches. Each size box has a cover to fit.

The NEC® requires that outlet boxes be 1 1/2 in. deep except when the use of a box of this depth will result in injury to the building structure or is impractical, in which case a box not less than 1/2 in. deep may be used. For switch boxes, the 2 1/2-in. depth is the most widely



73.15

Figure 9-17.-Types of outlet boxes.

used. The NEC® also requires that the outside edges of outlet and switch boxes without flush plates NOT be recessed more than 1/4 in. below the surface of the finished wall.

Receptacles

RECEPTACLES are used to plug in lights and appliances around the building. Some of the types of receptacle commonly used in interior wiring are discussed in the following paragraphs in the order of their frequency of use.

A CONVENIENCE OUTLET (fig. 9-18) is a duplex receptacle with two vertical or T-slots and a round contact for the ground. This ground is connected to the frame of the receptacle and is grounded to the box by way of screws that secure the receptacle to the box.

A RANGE RECEPTACLE (fig. 9-19) maybe either a surface type or a flush type. It has two slanted contacts and one vertical contact and is rated at 50 A. Receptacles for clothes dryers are similar but are rated at 30 A. Range and dryer receptacles are rated at 250 V and are used with three-wire, 115/230 V, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 V is made with two horizontal slots and one round contact for the ground.

Also used in the Navy are strips that allow movement of the receptacle to any desired location. These strips are available in 3-ft and 6-ft lengths and may even be used around the entire room. This type of outlet is particularly desirable in rooms where portable equipment or fixtures, such as drafting tables and audio-visual equipments, are used. Specialty outlets (weather-proof are used in all exterior locations because they resist weather damage.

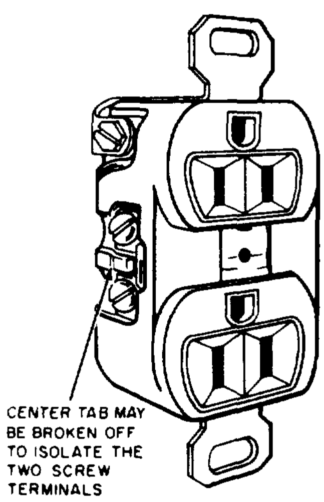


Figure 9-18.-A typical duplex convenience outlet.

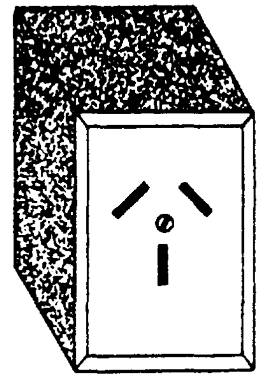


Figure 9-19.-Range receptacle.

Switches

For interior wiring, single-pole, three- or four-way toggle switches are used. Most of the switches will be single-pole, but occasionally a three-way system is installed, and on rare occasions, a four-way system.

A single-pole switch (fig. 9-20) is a one-blade, on-and-off switch that may be installed singly or in multiples of two or more in the same metal box.

In a three-way switch circuit (fig. 9-21), there are two positions, either of which may be used to turn a light ON or OFF. The typical situation is one in which one switch is at the head of a stairway and the other at the foot.

A four-way switch (fig. 9-22) is an extension of a three-way circuit by the addition of a four-way switch series.

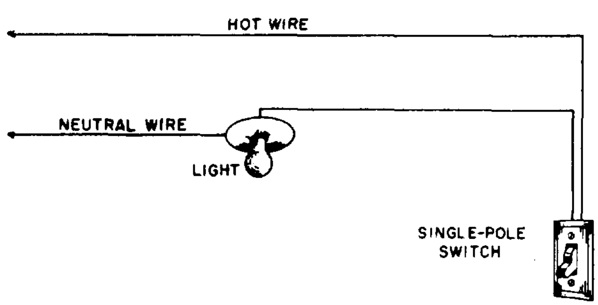


Figure 9-20.-Single-pole switch circuit.

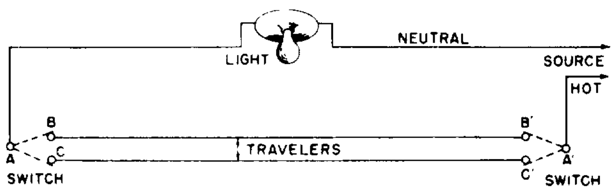


Figure 9-21.-Three-way switch circuit.

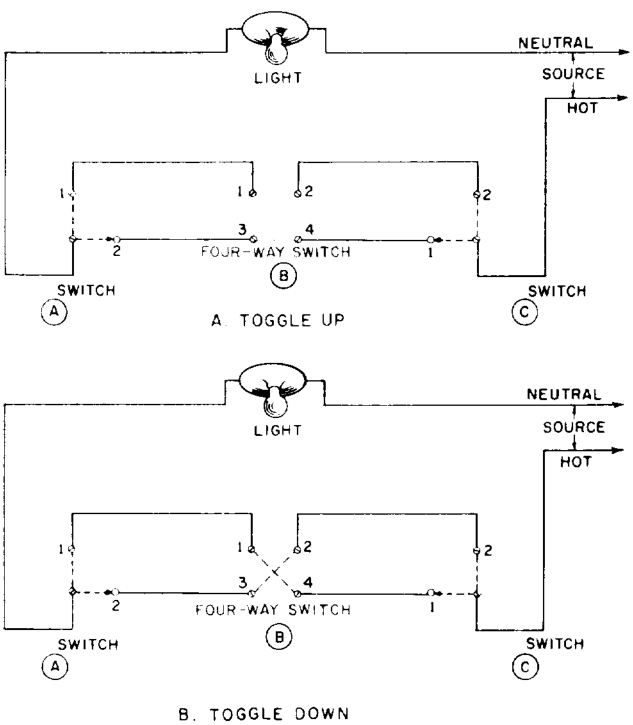


Figure 9-22.-Four-way switch circuit.

Note that three- and four-way switches can be used as single-pole switches, and four-way switches can be used as three-way switches. Some activities may install all small-wattage, four-way switches for all lighting circuits to reduce their inventories. However, three- and four-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (related maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch.

ELECTRICAL PLAN

The electrical information and layouts in construction drawings, just as the mechanical plan, are generally superimposed on the building plan and the plot plan.

In this chapter, we will address electrical plans as those drawings that pertain to the ELECTRICAL (POWER) DISTRIBUTION SYSTEM, which indicate outside power lines and appurtenances for multibuilding installations, and the INTERIOR ELECTRICAL WIRING SYSTEM.

As an EA3, the electrical layout for both light and power is your main concern. You will be required to draw electrical drawings and layouts from notes, sketches, and specifications provided by the designing engineer. Although you are not required to design the electrical wiring system, you must be familiar with the methods, the symbols, and the nomenclature, as well as the basic functions of the components associated with the electrical systems, its transmission and distribution, and the circuits hookup. In addition, you must also be familiar with the codes (both NEC® and local) and standards and specifications, and be able to apply that knowledge in drawing electrical plans.

STANDARDS AND SPECIFICATIONS REQUIREMENTS

Because the safety of the electrical system is of prime importance, it is imperative that all Navy electrical installations ashore conform to rigid standards and specifications. When preparing construction drawings, the EAs, like the CES, are required to follow the specifications issued by the Naval Facilities Engineering Command (NAVFACENGCOM). In particular, an EA working on electrical wiring and layout diagrams for electrical plans should refer to the latest edition of ANSI Y32.9 and ANSI Y14.15.

Codes

Code requirements and installation procedures offer protection for the consumer against unskilled electrical labor. Among other functions, the NEC® serves as a basis for limiting the type and wiring to be used, the circuit size, the outlet spacings, the conduit requirements, and the like. In addition, local codes are also used when separate electrical sections are applicable to the locale in which the building will be built. Be certain that you always have a copy of the latest edition of the NEC® available for your use.

Similarly, all of the types of electrical devices and fixtures included in the materials list prepared for electrical plans are to meet certain specifications and minimum requirements. An independent organization called Underwriters

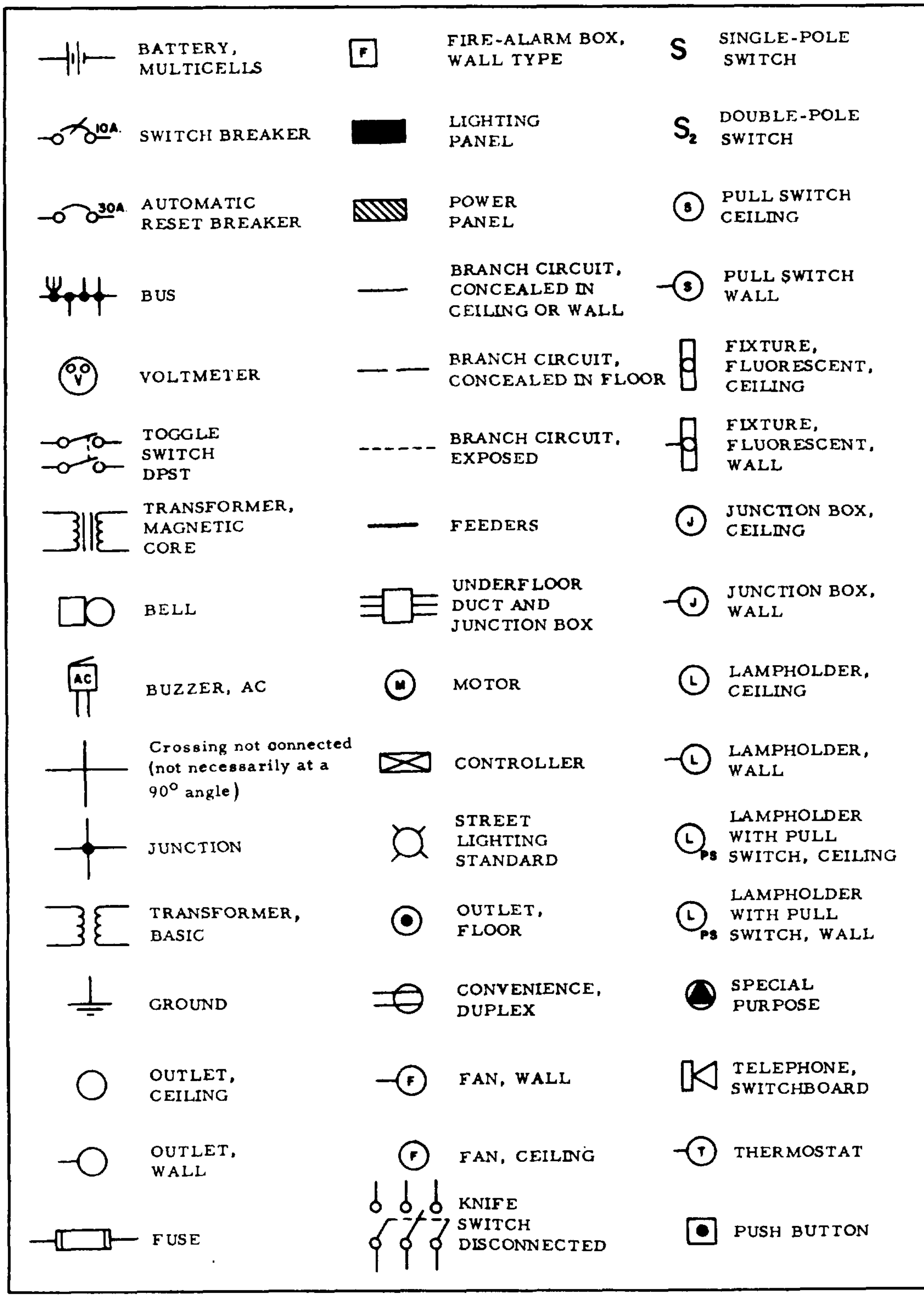


Figure 9-23.-Common types of electrical symbols.

Laboratories (UL) tests various electrical fixtures and devices to determine if they meet minimum specification and safety requirements as set up by UL. Those fixtures and devices that are approved may then bear UL labels.

Permit

In the SEABEEs, utility drawings (both mechanical and electrical) are thoroughly reviewed before an excavation (or digging) permit is granted and issued to the project subcontractor. Such action minimizes the hazards to personnel and underground structures during the construction process. All of the minor design changes and field adjustments must be noted and reflected on as-built and working drawings. Therefore, close coordination and cooperation must develop within and among all of the parties involved in the project to maintain periodic checks on red-lined prints so that information can be compared and verified as up to date.

ELECTRICAL SYMBOLS

The conventions used on the electrical plan are SYMBOLS that indicate the general layout, units, related equipment, fixtures and fittings, and routing and interconnection of various electrical wiring. The most common types of symbols used in electrical drawings are shown in figure 9-23. To see additional or special symbols, refer to the appendix section of this book and/or to ANSI Y32.9.

To draw in electrical symbols in an electrical drawing, as in drawing a mechanical plan, it is best to use templates. For example, a wiring symbol is generally drawn as a single line but with slanting "tick marks" to indicate the number of wires in an electrical circuit.

EXTERIOR ELECTRICAL LAYOUT (PLAN)

Exterior distribution lines (or network) deliver electrical power from the source (generating station or transmission substation) to various points of use. Figure 9-24 shows a typical layout, extracted from NAVFAC P-437, *Facilities Harming Guide,* of an exterior electrical network of buildings for a 100-man camp. This layout, in condensed form, shows a site plan of the camp area with facilities and the location of the electrical component system. Included in the electrical plan is a list of facilities (upper right-hand corner of fig. 9-24) that describes the corresponding item symbol, facility number, and quantity. An electrical load data table is also included in the drawing.

As an EA, you will be called upon to trace, modify, revise, and even review the workability of the drawing. It is therefore to your advantage not only to study and become familiar with the electrical plans, but also to gain a working knowledge of how the system works. NAVFAC P-437 offers a wide variety of plans, drawings, and applications for the Advanced Base Functional Component (ABFC) System for use in SEABEE construction.

INTERIOR ELECTRICAL LAYOUT (PLAN)

As we mentioned earlier, the electrical information on exterior electrical distribution is generally shown in the regular site or plot plan. The INTERIOR ELECTRICAL LAYOUT, however, is, for small buildings, drawn into a print made from the floor plan. On larger projects, additional separate drawing sheets are necessary to accommodate detailed information needed to meet construction requirements.

Figure 9-25 shows an electrical layout of a typical public works shop. Once again, note that the electrical information is superimposed on an outline taken from an architectural floor plan. In addition to the list of assemblies and electrical load table, a wiring diagram and panel schedule of a 225-A, three-phase circuit breaker is drawn. The underground service entrance (item 10 on the list of assemblies) delivers a four-wire, 120/208-V power into the building. Lighting circuits use a three-wire, No. 12 AWG (TW).

The following basic steps are suggested to guide you in the development of an interior electrical plan:

1. Show the location of the service panel and its rating in amps.
2. Show all of the wall and ceiling outlets.
3. Show all of the special-purpose outlets, such as telephones, communications, doorbells, and so forth.
4. Show all of the switches and their outlet connections.
5. Show convenience outlets.
6. If required, complete a schedule of electrical fixtures, symbols, legends, and notes necessary to clarify any special requirements in the drawing that are not stipulated in the specifications.

The steps suggested above can be put to practice in the next chapter following mastery of civil and architectural drawings.

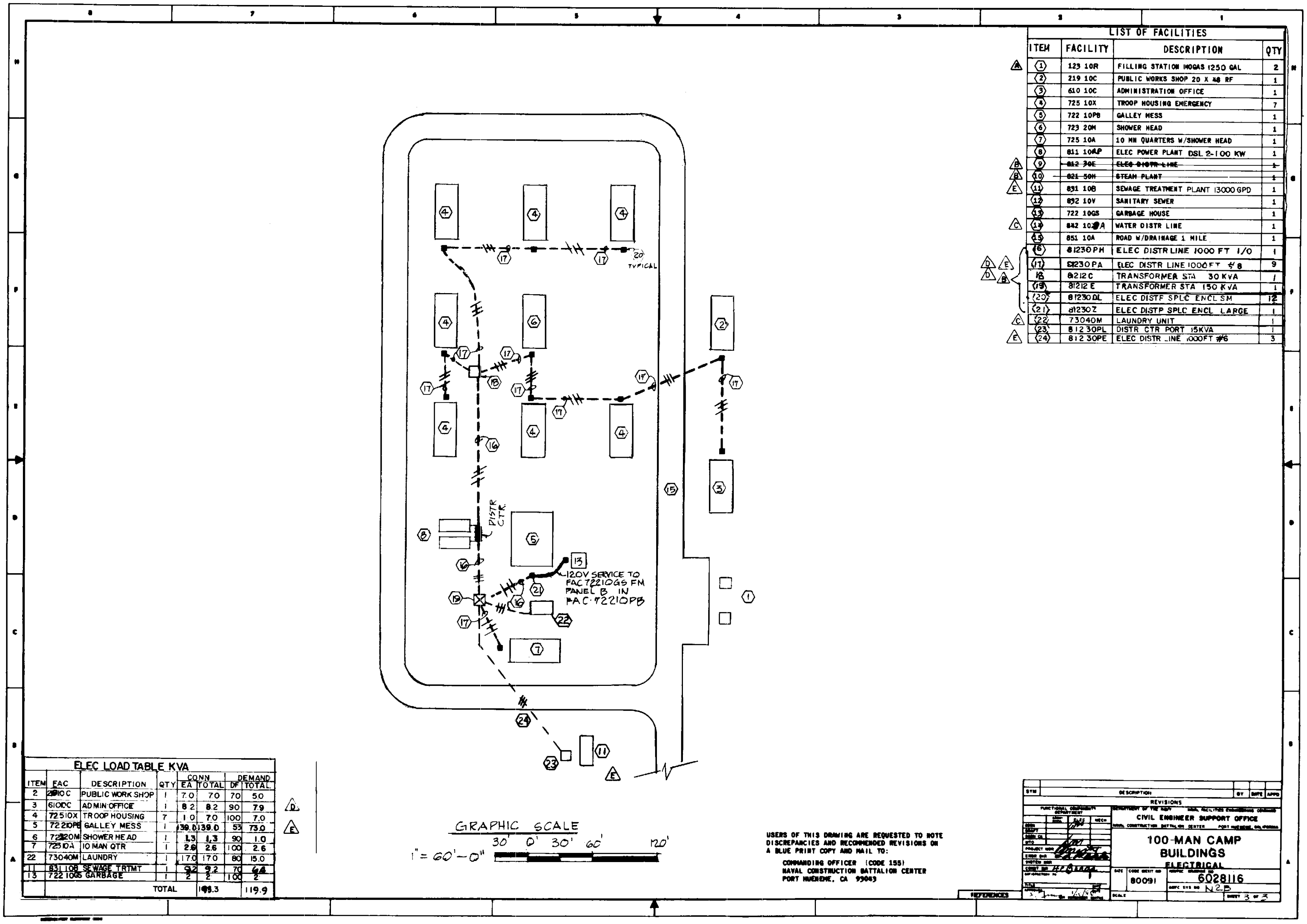


Figure 9-24.—Example of an exterior electrical plan.

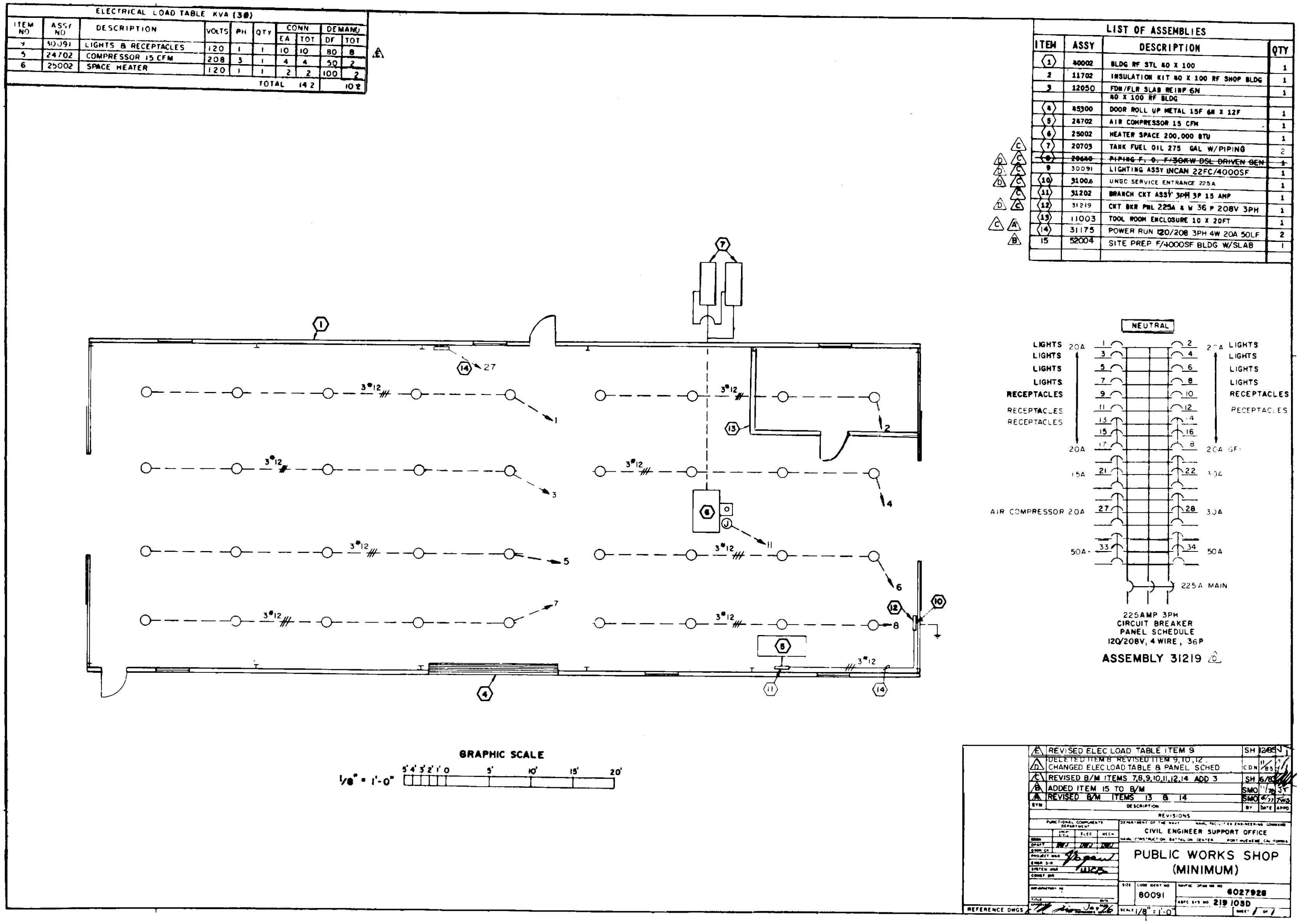


Figure 9-25.—Example of an interior electrical plan.